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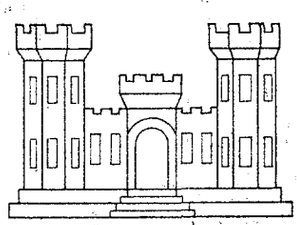
SURVEY REPORT

FOR

NAVIGATION, FLOOD CONTROL AND WATER POWER

MERRIMACK RIVER

MASSACHUSETTS AND NEW HAMPSHIRE



AUTHORIZED BY THE
RIVER & HARBOR ACT
APPROVED JUNE 20, 1938.

U.S. ENGINEER OFFICE
BOSTON, MASS.
APRIL 1, 1940.

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Returned to Merrimack R.

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SURVEY OF MERRIMACK RIVER, MASS. AND N. H.

Syllabus

The District Engineer finds that modification of the existing project for navigation on the Merrimack River is not warranted at this time.

He also finds that authorized flood control measures will provide a high degree of flood protection throughout the basin and that construction of a flood control reservoir on the Contoocook River is the only additional flood control measure justified at this time.

With respect to possibilities for multiple-purpose projects for flood control and power, the District Engineer reports that the provisions made for future power development at authorized flood control reservoirs will make possible a substantial increase in available hydroelectric capacity in the Merrimack Basin.

The District Engineer recommends that the existing flood control project be modified to provide for the increase in estimated costs of $700,000 due to inclusion of penstock intakes and related facilities in authorized flood control dams and to provide for the construction of the West Peterboro Reservoir on the Contoocook River at an estimated cost of $1,300,000, bringing the total authorized expenditure for the Merrimack River Basin to $23,000,000.

War Department
U. S. Engineer Office
3d Floor, Park Square Building
Boston, Mass.

April 1, 1940

Subject: Report on a Survey of the Merrimack River, Massachusetts and New Hampshire, for Navigation, Flood Control, and Water Power.

To: The Chief of Engineers, U. S. Army, Washington, D. C.
(Through the Division Engineer, North Atlantic Division, New York, N. Y.)

I. GENERAL

1. Authority.- This report is submitted in compliance with Section 8 of the River and Harbor Act approved June 20, 1938 (Public No. 685 - 75th Congress) which reads in part as follows:

> "Sec. 8. The Secretary of War is hereby authorized and directed to cause preliminary examinations and surveys to be made at the following-named localities, ********** Merrimack River, Massachusetts and New Hampshire, with a view to improvements for navigation, flood control, and water power."

2. Scope of Investigations.- A preliminary examination report was submitted on February 11, 1939, based on information obtained at five public hearings, and on data from prior reports, reconnaissance, and preliminary office studies. A survey to determine the advisability and cost of improvement and the local cooperation required was recommended by the Board of Engineers for Rivers and Harbors on March 20, 1939, and authorized by the Chief of Engineers on March 22, 1939. Field work was carried on intermittently, as required from July 1939 to March 1940. Data and results of the survey of possibilities for improvement for navigation, flood control, and water power are reported herein in separate sections. The views of local interests are summarized in the sections to which they apply. Complete transcripts of the five public hearings held in connection with the survey were submitted with the preliminary examination report.

3. Prior Reports.- A summary of the scope and recommendations of reports on the Merrimack River since 1930 is given in the following table:

TABLE 1 - PRIOR REPORTS

Date	Scope of Report and Section Covered	Where Published or Filed	Recommendations
1930	Report on Navigation, Flood Control, Power Development and Irrigation ("308" report)	H.Doc. No. 649, 71st Congress, 3rd Sess.	None. Concludes conditions not favorable for coordinated development at that time.
1936	Preliminary Examination Lowell to the sea (navigation)	Not Printed. Boston file No. Merrimack 168/30.	Unfavorable.
1938	Review of above report for the section from Haverhill to Newburyport.	Not printed. Boston file No. Merrimack 141/127.	Unfavorable.
1938	Survey of Merrimack River Basin for flood control.	H.Doc. No. 689, 75th Cong., 3rd Sess.	Favorable for comprehensive system of reservoirs and related flood works.
1938	Review of H.Doc. No. 649, 71st Cong., 3rd Sess. - Navigation, flood control, power development and irrigation.	Not printed. Board of Engineers file No. 4793/7.	Unfavorable. (Based on data obtained prior to Sept. 1938 flood.)

4. Description of the Basin.- The Merrimack River Basin lies in the central portion of the New England area and extends from the White Mountain region southward through central and southern New Hampshire into the northeastern corner of Massachusetts. (See map, Plate 1.) The basin has a length of 134 miles, a maximum width of 68 miles, and a total drainage area of 5,015 square miles*, of which 3,815 square miles, or 76 per cent, are in New Hampshire and 1,200 square miles, or 24 per cent, in Massachusetts. The lake and pond area, amounting to 213 square miles, or about 4.25 per cent of the total basin area, exercises almost complete control over about 13 per cent of the total basin area. The topography ranges from rugged with steep slopes and narrow valleys in the northern portion to hilly and gently rolling in the lower valley. The present drainage pattern consists of irregular courses over deep glacial overburden and follows only generally the trends of the pre-glacial major bedrock basins. Regular stream gradients are being established gradually, the upper river and some tributaries having become deeply entrenched in the soils. However, lakes and marshes are still present, especially in the lower reaches. The bedrock is generally of granite or gneiss, with local areas of quartzite, slate or schist. The overburden is generally a gravelly and only slightly silty sand.

5. Description of the Main Stream.- The Merrimack, the fourth largest river in New England, is formed by the junction of the Pemigewasset and Winnipesaukee Rivers at Franklin, New Hampshire. The Pemigewasset River, the main stream above Franklin, has its source

* Includes 211 square miles from which the normal flow is diverted for the Metropolitan Water Supply District.

in the White Mountains at an elevation of about 2,700 feet above mean sea level. It flows in a southerly direction to Franklin, where it joins with the Winnipesaukee. From this junction, the Merrimack continues in a southerly direction to Lowell, Massachusetts, where it turns abruptly through an angle of about 110 degrees and flows in an east-northeasterly direction to tidewater at Haverhill and thence to the Atlantic Ocean near Newburyport, Massachusetts, 35 miles north of Boston. The total distance thus covered is 186.2 miles through a total fall of 2,700 feet at an average rate of 14.5 feet per mile. The average daily discharge for a 55-year period of record at Lawrence, Massachusetts (drainage area 4,461 square miles) is 6,940 c.f.s; the maximum, 174,000 c.f.s. (March 1936), and the minimum, 0 c.f.s. (caused by mill storage).

6. Description of Tributaries.- The principal tributary is the Pemigewasset, which drains one-fifth of the Merrimack Basin. The streams in the Pemigewasset watershed are short and steep with narrow valleys. Next largest tributary is the Contoocook, a meandering stream with alternate reaches of steep and flat slopes. The Pemigewasset and Contoocook are the principal flood-producing tributaries. The largest southern tributaries, the Nashua and Concord Rivers, are flat and sluggish, with meandering courses through low, marsh areas. General data on all tributaries are summarized in the following table:

TABLE 2 - TRIBUTARIES OF THE MERRIMACK RIVER

Tributary	Junction with Main River at Mile:	Drainage Area in Sq.Mi.	Elevation of Head-Waters	Length in Miles	Slope in Feet Per Mile	Estimated Max. Flow (cfs/sq.mi.)
East Branch(a)	169.8	115	2700	16	125	163
Baker River(a)	147.2	213	3000	34	75	134
Squam River(a)	140.8	73	562	4	24	25
Newfound River(a)	129.9	98	586	3	81	50
Smith River(a)	127.4	88	816	11	45	94
Pemigewasset R.	115.7	1021	1970	64	27	76
Winnipesaukee R.	115.7	486	504	10	23	15
Contoocook R.	100.7	766	1200	67	14	61
Soucook River	85.8	91	1000	28	29	80
Suncook River	82.9	260	808	39	16	47
Piscataquog R.	71.3	220	656	24	22	100
Souhegan River	62.3	220	1100	35	29	99
Nashua River	54.8	530(b)	800	56	13	48
Beaver Brook	39.8	95	287	12	20	50
Concord River	38.8	406(c)	300	41	6	17

(a) Tributary to the Pemigewasset River.
(b) Includes 118 square miles from which flow is diverted for water supply.
(c) Includes 93 square miles from which flow is diverted for water supply.

7. General Climate and Hydrology.- In general, the basin has a climate of variable weather characterized by frequent, but short, periods of heavy precipitation and with temperatures ranging from well below freezing for three to four months in winter to moderately high summer temperatures. The mean annual temperature is 45.6 degrees Fahrenheit. Although extremes of 106 degrees at Lawrence, Massachusetts, and -36 degrees at Franklin, New Hampshire, have been recorded, extended periods of intense heat or cold are rare. The mean annual precipitation of 40.24 inches is very uniformly distributed throughout the year. The annual snowfall is moderately heavy, ranging from about 45 inches in the lower basin to 85 inches in the headwaters.

8. General Development of the Basin.- The total population of the basin in 1930 was about 811,000, of which 555,000 are in Massachusetts and 256,000 in New Hampshire. Eighty per cent of the inhabitants

are concentrated in cities and towns of over 2,500 population, located principally in the highly industrialized lower valley. Farming and lumbering were originally carried on throughout the basin. At the present time, however, the northern portion, which lies in the White Mountain region, is largely recreational and farming activities have been concentrated into dairy, poultry, fruit and truck-farming groups in the lower valley. The entire lower valley is highly developed industrially, the principal products being textiles, leather goods, and wood products. The highway system throughout the basin is adequate, both as to truck routes and connecting roads. The principal railroad is the Boston and Maine. Parts of the lower basin are also served by the Boston and Albany and the New York, New Haven and Hartford Railroads. The river is improved for navigation only in the tidal portion from Haverhill to the mouth, the existing project providing for a 7-foot channel, 150 feet wide. (See Section II.) Flood control reservoirs and related flood works have been authorized (see Section III) and work has been started on two reservoirs. Local channel improvements at Fitchburg and Lowell, Massachusetts, and construction of a flood wall at Haverhill, Massachusetts, were accomplished in 1936, 1937, and 1938 as Emergency Relief Appropriation projects. The Merrimack Basin has been extensively developed for water power, but there is a deficiency of power storage. (See Section IV.) About 250,000 acre-feet of storage are utilized for water supply purposes. The need for improvement of the river for navigation, flood control, and water power is discussed in separate sections following.

II. NAVIGATION

9. Projects and Operations.- The portions of the Merrimack River improved for navigation lie entirely in the tidal section and are covered by two projects, Newburyport Harbor, Mass., and Merrimack River, Mass. (See Plate 2.) The existing project for Newburyport Harbor was adopted in 1880, and, with subsequent modifications, provides for two rubble jetties at the entrance so as to secure a permanent channel across the bar 1,000 feet wide and 17 feet deep at mean low water, and a training dike across the basin at the north end of Plum Island. Dredging on the bar was authorized by the River and Harbor Act of July 25, 1910. This project as a whole is 97 per cent completed. The existing river project was adopted in 1899 and provides for a channel 7 feet deep and 150 feet wide from Newburyport to the railroad bridge at Haverhill. This project was completed in 1907.

10. Appropriations and Costs.- The total appropriations and costs to March 1, 1940, were as follows:

	Appropriations	Costs	
		New Work	Maintenance
Newburyport Harbor	$ 728,330.61	$463,843.62	$255,486.99
Merrimack River	518,466.72	369,891.49	147,865.10
Total	$1,246,797.33	$833,735.11	$403,352.09

11. Navigable Status of River.- According to the latest surveys the controlling depths at mean low water in the improved section of the river are 10.3 feet in the entrance, 8.5 feet to the wharves at Newburyport, and 7 feet from Newburyport to Haverhill. The river above Haverhill is only partially navigable. From Mitchell's Falls to the dam at Lawrence it becomes a series of detached ponds whenever the natural flow is stopped for storage by the mills. There is a canal around the dam

at Lawrence, and the pool above is navigable for boats drawing 2 to 3 feet for about 8 miles upstream to Hunts Falls. There is a canal around the dam at Lowell, and the pool above this extends 17-1/2 miles upstream to Merrimack, N.H., providing a channel about 8 feet deep, but in places obstructed by ledges and boulders. In 1931, the head of navigation of the Merrimack River was designated as about 4 miles above the mouth of the Nashua River, which is the upper limit of the pool above the dam at Lowell.

12. Prior Navigation Reports.- The improvement of the Merrimack River for navigation has been the subject of numerous reports covering suggested channels in various sections of the river from the mouth to Manchester, N.H., and at proposed depths varying from 7 to 25 feet at mean low water. From 1826 to the present time, 28 reports have been submitted, and all reports since 1913 have been unfavorable to further improvement of the Merrimack River for navigation. A summary of the scope and recommendations of reports since 1930 is given in Table 1 following paragraph 3.

13. Commerce.- The present water-borne commerce consists entirely of petroleum products delivered at Newburyport in barges drawing from 9 to 11 feet. Prior to 1936, this traffic extended to Haverhill, but was discontinued because of shoals in the channel created by the flood of March of that year. This channel has been restored to project dimensions for the possible resumption of traffic during the season of 1940. A comparison of the traffic for the 10-year period prior to 1939 is shown below:

TABLE 3 - WATER-BORNE COMMERCE - NEWBURYPORT HARBOR AND MERRIMACK RIVER

Year	Over Wharves at Newburyport		Additional Traffic - Sand (1)		Cargoes in Transit Other Cargoes (2)	
	Tons	Value	Tons	Value	Tons	Value
1929	51,403	$628,013	43,800	$52,600	19,511	$565,096
1930	47,858	703,748	48,000	57,600	4,696	140,406
1931	38,659	443,471	45,290	45,290	19,929	401,666
1932	51,779	429,057	34,478	34,478	12,443	263,371
1933	29,494	317,058	29,836	29,836	13,707	272,827
1934	19,598	227,061	40,344	40,344	14,841	281,831
1935	24,410	256,520	36,331	36,331	17,344	312,947
1936	20,702	283,774	29,600	29,600	---	---
1937	31,156	260,947	30,530	30,530	---	---
1938	11,196	181,683	28,128	28,128	---	---

(1) Sand dredged at mouth of river and shipped in barges direct to neighboring points along the coast.

(2) Merrimack River traffic.

14. Terminal Facilities.- The terminal facilities at Newburyport and Haverhill are adequate for the present commerce on the river. There are no water terminals above Haverhill. The manufacturing plants throughout the Merrimack Valley have been laid out without reference to the possibility of the river being made navigable, and a large expenditure would be necessary to provide suitable terminals and to adapt existing plants to the handling of water-borne freight.

15. Improvement Desired.- The views of local interests on possible navigation improvements were invited at a public hearing held at Lowell, Mass., on November 21, 1938. No suggestions were received and the possibility of an additional hearing was discussed. Local authorities later disclosed that they did not consider another hearing necessary as they had no evidence to submit other than that already furnished at the public hearing held at Haverhill, Mass., on April 12, 1938, in connection with preliminary examination of the river from Newburyport to Haverhill. At that time the desired improvement was a channel 9 feet deep and 200 feet wide to Haverhill, with a suitable turning basin below the Haverhill-Bradford highway bridge.

16. Possible Plans of Improvement.- In the absence of any specific plan of improvement desired by local interests at this time, consideration has been given to two previously suggested plans with a view to determining the possibilities for navigation improvements in combination with possible flood control and water power improvements. Typical of recent navigation plans are: (1) the 9-foot by 200-foot channel from Newburyport to Haverhill suggested by local interests in April 1938 and reported on adversely in November 1938, and (2) the 18-foot by 200-foot channel from the mouth to Lowell reported adversely in 1922 (H. Com. Doc. No. 1, 68th Cong., 2nd Sess., which was a review of H. Doc. No. 1813, 64th Cong., 2d Sess.). The estimated costs of these plans, based on quantities determined in the original reports and with present-day unit prices, are as follows:

	Estimated First Cost	Estimated Annual Maintenance	Total Estimated Annual Charge
(1) 9'x200' channel to Haverhill	$ 703,000	$ 7,000	$ 40,000
(2) 18'x200' channel to Lowell	23,000,000*	250,000	1,300,000

* Includes $9,000,000 for terminals, alterations to bridges and collateral improvements.

17. Prospective Benefits.- There is little likelihood that any substantial traffic would result from a deepening of the channel either to Haverhill or the industrial cities upstream. Any estimate of this traffic would be purely conjectural. Conditions are even less favorable at this time than when previous studies were made. The general decline in industry in this region, the trend toward the use of large deep-draft carriers, and the development of efficient trucking facilities give a decided advantage to neighboring deep water ports, such as Boston, Lynn and Beverly, which would offer much lower freight rates, particularly

on coal and petroleum products. The prospective commerce on a 9-foot by 200-foot channel to Haverhill would afford little, if any, increase in benefits over the existing 7-foot by 150-foot channel. A deeper channel, 18 feet by 200 feet, would be adequate for the smaller vessels commonly in use in coal and oil traffic, but the benefits of any reasonably prospective amount of such traffic would be only a fraction of the cost of the improvements necessary for their realization.

18. Discussion.- Previous investigations have shown conclusively that further improvement of the Merrimack River for navigation is neither necessary nor economically justified. Consideration of the possibilities of navigation improvements in conjunction with possible flood control or water power improvements discloses no circumstances tending to modify this conclusion. Flood control or conservation storage projects would have no effect on the navigable channel in the tidal section below Haverhill, and the maximum increase in low water flow that could be afforded by such projects would have only a minor effect in reducing the expenditures necessary for navigation improvements above Haverhill. Channel improvements for flood control in the lower river of sufficient extent to have benefit for navigation as well would cost much more than alternate separate measures for either flood control or navigation without appreciable increase in total benefits. The lower river is already highly developed for water power purposes and there is no economic possibility of further development by combination with navigation improvements.

19. Conclusions.- There is no economically justified possibility for improvement of the Merrimack River for navigation beyond the limits of the existing project, either for navigation alone or in combination with possible flood control and water power improvements.

III. FLOOD CONTROL

20. General Flood Situation.- The lower Merrimack Valley is thickly settled and highly developed industrially. There are seven centers of population of over 25,000 each (see Plate 1) in which residential, commercial, and industrial developments are concentrated near the river banks and, in some cases, encroaching seriously on the flood plain. The average annual flood for the 91-year record at Lawrence, Massachusetts, (drainage area 4,461 square miles or 89% of the total basin area) is about 44,200 cubic feet per second. The stage at which flood loss begins is about 47,700 cubic feet per second. Serious damage does not occur until flows of about 65,000 cubic feet per second are reached. Floods of this magnitude or greater have occurred 10 times in the 91 years of official record at Lawrence, but, prior to 1936, five of these flows were about 65,000 cubic feet per second, the stage at which serious damage just begins, and 3 of the flows were about 80,000 to 90,000 cubic feet per second, causing moderately severe flood losses. The two highest floods in the 91-year record have occurred during a recent three-year period. The greatest flood of record was that of March 1936, when the maximum daily discharge of 159,000 cubic feet per second at Lawrence exceeded the highest previously recorded, in April 1852, by nearly 80%. Two years later, in September 1938, the second highest flood of record was experienced. The unprecedented damages caused by the record floods of 1936 and 1938 brought into focus the need for flood protection measures in this basin. As a result of studies undertaken after the 1936 flood, a comprehensive plan for flood control was adopted in June, 1938. The additional data available since the September, 1938 flood have been taken into account in this report.

21. Precipitation and Stream Flow Data.- There are records available for about 40 precipitation observation stations in and near the Merrimack Basin. About half of these records are from 50 to 100 years in length. The distribution of the stations throughout the watershed is such that adequate data for flood control purposes are readily obtainable except in the northern headwater areas where the stations are least numerous and precipitation values most variable. Stream flow records are available for 23 U.S. Geological Survey gaging stations affording satisfactory data for the main stream and principal tributaries. There are also records of gage heights maintained by private interests and peak flow determinations for the 1936 and 1938 floods at numerous points throughout the basin. In general, better than average data are available for determination of precipitation and discharge frequency, maximum meteorological conditions, rainfall-run-off relations, and unit hydrographs. A summary of hydrological data is given in the following table.

TABLE 4 - HYDROLOGICAL DATA - MERRIMACK BASIN

Month	Mean Discharge at Lawrence*			Precipitation in Inches	Run-off as % of Precipitation
	Cubic Feet Per Second	Cubic Feet Per Second Per Square Mile	Run-off in Inches		
January	6,000	1.34	1.55	3.38	46
February	6,260	1.40	1.46	3.26	45
March	12,600	2.82	3.26	3.58	91
April	17,800	3.99	4.45	3.14	142
May	10,300	2.31	2.68	3.07	87
June	5,720	1.28	1.43	3.37	42
July	3,500	.78	.91	3.66	25
August	3,050	.68	.79	3.52	22
September	3,060	.69	.77	3.49	22
October	3,700	.83	.96	3.10	31
November	5,360	1.20	1.34	3.39	40
December	5,940	1.33	1.54	3.28	47
Annual	Mean 6,940	Mean 1.55	Total 21.14	Total 40.24	53

*These figures are based on a record of 55 years (1880 to 1934).

22. Records of Past Floods.- The ten highest floods of the 91-year record at Lawrence, arranged chronologically, are as follows:

TABLE 5 - FLOOD FLOWS - MERRIMACK RIVER AT LAWRENCE

Order of Magnitude	Date of Peak Day	Average Discharge of Peak Day (c.f.s.)	No. of Years Since Previous High Flood
3	April 23, 1852	90,200	-
10	March 20, 1859	64,100	7
4	April 21, 1870	82,900	11
8	December 12, 1878	66,000	8
9	April 16, 1895	65,300	17
5	March 3, 1896	82,150	1
6	November 6, 1927	66,600	31
7	April 20, 1933	66,500	6
1	March 20, 1936	159,000	3
2	September 23, 1938	118,000	2

23. Description of Major Floods.- The flooding in March 1936 was general throughout the basin and greatly exceeded all previous official records since 1850 and unofficial records since 1785. Complete data on this flood were reported in H. Doc. No. 689, 75th Cong., 3rd Session. The flood of September 1938 was the second largest of record for the main stream and most tributaries and the greatest of record at a few locations, principally on the Contoocook River. The flood was caused by heavy rain during the period September 18 to 22 falling on watersheds well saturated by previous rain from September 12 to 16. Flood losses were less than might ordinarily be expected for the stages reached because of the "flood consciousness" retained by the affected population from the record flood only 2 years before. Flood warnings were heeded

and large amounts of goods and equipment were moved to safe locations. During the flood period transportation, utilities, and communications were further crippled by the occurrence of a hurricane which affected the entire Merrimack Basin as well as most of New England and eastern New York.

24. Extent and Character of Flooded Area.- The principal towns and cities in the basin are located on the main stream (see Plate 1) and a considerable amount of industrial property is situated immediately adjacent to the normal river channel. The commercial sections of several communities are also located near the waterfront. These developments, together with power plants and bridges, are subject to severe losses within a comparatively small area of flooding. The amount of agricultural land flooded is extensive at extreme stages, but the damage is moderate because most floods in the basin occur in the spring before crops have been planted. The utility, highway, and railroad facilities of the basin are extensive, but because main routes generally follow the streams in order to serve the population concentrations and take advantage of favorable topography, transportation and communication are seriously affected during major floods.

25. Flood Losses.- A comprehensive survey of the damages caused in March 1936 was made immediately following the flood. Stage-damage and stage-frequency relations were established at that time. Additional data obtained after the flood of September 1938 were used to extend and revise the 1936 computations. The computed average annual flood loss on the main stream and principal tributaries, based on the revised data for losses and frequencies, is $1,610,000. Detailed statistics on flood damages and description of the method of computation of the average annual flood loss are given in an appendix (Section B). The following tabulation shows the extent and character of flood losses in the two major floods

of record. The 1936 figures are more typical as to proportion of losses by type. In 1938, the amounts of damage of all types except railroad and highway were less than would normally be expected for the flood stages experienced because much damageable property was moved to safe levels (see paragraph 23).

TABLE 6. FLOOD LOSSES - MERRIMACK BASIN

Type of Loss	1936 Flood		1938 Flood	
	In Dollars	In % of Total	In Dollars	In % of Total
Industrial	$13,300,000	38	$ 1,000,000	17
Commercial	4,200,000	12	600,000	10
Residential	4,300,000	12	360,000	6
Agricultural	800,000	2	300,000	5
Railroads	3,400,000	10	1,500,000	25
Highways	4,000,000	12	2,000,000	33
Utilities	1,800,000	5	120,000	2
Public	3,200,000	9	120,000	2
Total	$35,000,000		$ 6,000,000	
% Direct	56		60	
% Indirect	44		40	

26. Existing Project.- The Flood Control Act approved June 22, 1936, authorized the construction of a system of flood-control reservoirs in the Merrimack River Basin at an estimated cost of $7,725,000 for construction and $3,500,000 for lands and damages. The Flood Control Act approved June 28, 1938, approved the general comprehensive plan for flood control and other purposes as set forth in House Document No. 689, 75th Congress, 3rd Session, for which the estimated cost is $13,000,000 for construction and $8,000,000 for lands and damages, and modified the previously authorized project to provide, in addition to the construction of a system of flood-control reservoirs, related flood control works which may be found justified by the Chief of Engineers.

27. Status of Work on Existing Project.- Three flood control reservoirs, Franklin Falls, Blackwater, and Hopkinton-Everett, have been proposed for construction under the existing project (see Plate 1). General data and the status of work on the reservoirs are summarized in the following table.

TABLE 7. DATA ON EXISTING PROJECT RESERVOIRS

Item	Franklin Falls Reservoir	Blackwater Reservoir	Hopkinton-Everett Reservoir	Total Reservoir System
Drainage Area Controlled (Sq.Mi.)	1,000	127.5	490	1,617.5
Flood Control Storage				
- in acre-feet	170,000	46,000	160,000	376,000
- in inches	3.2	6.8	6.1	4.4
Estimated Costs				
Dam, spillway & outlets	$5,705,000	$ 630,000	$7,216,000	$13,551,000
Penstocks and related facilities	395,000	180,000	125,000	700,000
Land & rights-of-way	1,300,000	260,000	1,709,000	3,269,000
Relocations	700,000	230,000	2,450,000	3,380,000
Total Estimated Cost	$8,100,000	$1,300,000	$11,500,000	$20,900,000
Date of Approval as Definite Project	Feb.15,1937	Jan.18,1940	Mar.12,1940	---
Date Construction Started	Oct. 1938	Jan. 1940	*	---
Estimated Completion Date	June 1942	Sept. 1941	*	---
Estimated Amount Expended on April 1, 1940	$ 650,000	$ 65,000	$ ---	$ 715,000

*Not yet scheduled.

In addition to the reservoir system outlined above, the construction of local flood protection works to supplement the reservoir control at several main stream damage centers is contemplated (see Plate 1). Local protection for the upper Contoocook River in the vicinity of East Jaffrey, N.H. by means of headwater improvements is also contemplated. Definite project plans for these related flood control works under the existing project are still in the course of preparation. The estimated cost of the measures under consideration is as follows:

Locality	Estimated Cost
Lowell, Mass.	$ 250,000
North Andover, Mass.	150,000
Nashua, N.H.	100,000
East Jaffrey, N.H.	300,000
Total	$ 800,000

28. Status of Other Flood Control Measures.- Local flood protection work was accomplished by the Corps of Engineers at the following localities with funds from the Emergency Relief Appropriation Acts of 1935, 1936, and 1937.

Locality	Type of Work	Construction Period	Total Federal Cost
Fitchburg, Mass.	Channel improvement	Aug.1936 to June 1938	$1,370,000
Haverhill, Mass.	Flood wall & conduit	Sept.1936 to Mar.1938	$1,744,000
Lowell, Mass.	Channel improvement	Dec.1936 to June 1938	$ 794,000

The City of Lawrence has sponsored two projects under the Works Progress Administration involving dikes and walls along the north bank above the dam on the Merrimack River and on the west bank of the Shawsheen River in that city. The City of Lowell has planned two W.P.A. projects for flood protective works on Hale's Brook and the Concord River in Lowell. Work has been started on the project above the dam in Lawrence, but no data are available as to expected completion dates of any of the projects.

29. Improvement Desired.- The views of local interests concerning possible flood control measures were solicited at five public hearings held in different sections of the basin. Many suggestions were received, ranging from comprehensive reservoir control to local protection by means of dikes, small reservoirs, channel improvements, and evacuation of local areas. At the time of the public hearings, no appreciable progress had been made on the comprehensive flood control measures authorized by the existing project. Taking into account the

measures completed, under construction, or contemplated under the existing project, most of the improvements desired by local interests will be accomplished or made unnecessary by satisfactory alternate measures. The remaining possibilities for flood control, which are analyzed in this report, cover the entire range of improvements desired by local interests.

30. Effect of Existing Project Flood Control Measures. The effectiveness of the reservoir system is illustrated on Plate 3. If the flood control measures under construction or proposed under the existing project had been in operation since 1850, practically all flood damage would have been prevented for all floods except in 1936. It will be noted that the flood of March 1936, which reached a stage of as much as 20 feet above flood stage in certain sections, would be reduced to stages of from 3 to 8 feet above flood stage for most of the main stream. Even in those reaches where an appreciable depth of flooding would still occur, the amount of damage possible will be small. Practically complete elimination of damage will be provided in the upper reaches of the main stream and a high percentage of control is afforded downstream reaches as well. The effectiveness of existing project measures in terms of reduction of estimated average annual damages is as follows:

Section of Basin	Average Annual Damages Without Flood Control	Average Annual Damages Prevented by Existing Project	% of Damages Prevented
Merrimack River in Mass.	$ 607,000	$ 367,000	60
Merrimack River in N.H.	813,000	697,000	86
Penigewasset River (N.H.)	58,000	---	0
Contoocook River (N.H.)	122,000	32,000	26
Piscataquog River (N.H.)	10,000	8,000	80
Total	$1,610,00	$1,104,000	69

31. Possible Additional Measures.- The principal areas in which a greater degree of flood protection appears desirable are: (1) on the Penigewasset River above Franklin Falls Reservoir, (2) on the

Contoocook River above Hopkinton-Everett Reservoir, and (3) at the principal downstream damage centers. The possibilities for protection in these areas by means of additional reservoir control and local measures are discussed in following paragraphs. The priority of the principal tributaries for possible additional reservoir control is illustrated on Plate 4. Without the reservoir control contemplated under the existing project the Penigewasset and Contoocook Rivers account for approximately 29 and 20 per cent, respectively, of the uncontrolled peak flows at downstream damage centers. Upon completion of the Franklin Falls, Blackwater, and Hopkinton-Everett Reservoirs, the Penigewasset and Contoocook flows will be reduced as much as 50 per cent to 65 per cent and the reduced components of these tributaries will be 15 and 12 per cent, respectively, of the reduced main stream flood peaks. Even with this substantial reduction in flow, additional control of the Penigewasset or Contoocook would have greater effect in reducing main stream flood peaks than control of any other tributary. The only other large tributary component is that of the Nashua River. Reservoir control on this stream would be comparatively ineffective because artificial storage would, to a large extent, merely replace natural valley storage and would, therefore, afford little desynchronization of its contribution to the main stream peak.

32. Penigewasset Watershed.- The Franklin Falls Reservoir was selected for construction under the existing project after consideration of 21 prospective sites in the Penigewasset watershed. All sites originally studied, as well as additional sites suggested by local interests and the New Hampshire Water Resources Board, have been given further consideration as possible additional reservoir control to supplement the selected Franklin Falls Reservoir. The prospective benefits of additional reservoirs in this watershed are the prevention of average annual flood losses of about $58,000 in the reaches above

Contoocook River above Hopkinton-Everett Reservoir, and (3) at the principal downstream damage centers. The possibilities for protection in these areas by means of additional reservoir control and local measures are discussed in following paragraphs. The priority of the principal tributaries for possible additional reservoir control is illustrated on Plate 4. Without the reservoir control contemplated under the existing project the Penigewasset and Contoocook Rivers account for approximately 29 and 20 per cent, respectively, of the uncontrolled peak flows at downstream damage centers. Upon completion of the Franklin Falls, Blackwater, and Hopkinton-Everett Reservoirs, the Penigewasset and Contoocook flows will be reduced as much as 50 per cent to 65 per cent and the reduced components of these tributaries will be 15 and 12 per cent, respectively, of the reduced main stream flood peaks. Even with this substantial reduction in flow, additional control of the Penigewasset or Contoocook would have greater effect in reducing main stream flood peaks than control of any other tributary. The only other large tributary component is that of the Nashua River. Reservoir control on this stream would be comparatively ineffective because artificial storage would, to a large extent, merely replace natural valley storage and would, therefore, afford little desynchronization of its contribution to the main stream peak.

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Franklin Falls and perhaps up to $100,000 annually in downstream reaches from Lowell to Haverhill. No reservoir or group of reservoirs has been found capable of obtaining enough of these benefits to warrant construction for flood control alone. The only apparent economically feasible possibility is a multiple-purpose project at the Livermore Falls site. This development in conjunction with Franklin Falls Reservoir, would provide additional annual flood control benefits of $83,000 at an annual cost chargeable to flood control of only $14,000. The project depends, however, on the realization of nearly one million dollars annually in power revenue for justification. The possibilities of this project are discussed further in Section IV of this report.

33. Contoocook Watershed.- Fifteen reservoir sites were originally studied in this watershed leading to the selection of Blackwater and Hopkinton-Everett Reservoirs under the existing project. Further consideration has been given these sites, as well as other sites suggested by local interests and the New Hampshire Water Resources Board, as possible additional control to supplement the downstream benefits afforded by Blackwater and Hopkinton-Everett and to afford protection along the upper Contoocook River. There are several prospective multiple-purpose projects which have possible future value for conservation storage and power development, but which have insufficient value for flood control to warrant their construction at this time. (See Section IV.) The most favorable flood control possibility in the Contoocook watershed is the proposed West Peterboro Reservoir, a site suggested by the New Hampshire Water Resources Board. This project, a small headwater reservoir which affords a high degree of control for the upstream reaches of the Contoocook River from Peterboro to Henniker, is described fully in paragraphs 35 to 39.

34. Other Tributaries.- About 35 prospective reservoir sites have been investigated on tributaries other than the Penigewasset and Con-

tocook Rivers. None of these sites affords sufficient reduction of flood stages at downstream damage centers to warrant development. The principal reasons for the lack of justification for prospective reservoirs on these tributaries are:

(a) The comparatively minor influence of the tributaries on main stream peak flows as illustrated on Plate 4 and discussed in paragraph 31.

(b) The lack of economical dam sites because of topography less rugged than in the Pemigewasset and Contoocook Basins.

(c) In some cases, the amount of natural valley storage is so large that artificial storage provides little desynchronization of the tributary peak flows with main stream peak flows.

35. West Peterboro Reservoir.- The proposed West Peterboro Reservoir is located in Hillsboro and Cheshire Counties in New Hampshire. The dam site is on Nubanusit Brook, a tributary of the Contoocook River, near the village of West Peterboro, N.H., about 35 miles southwest of Concord, N.H. and 60 miles northwest of Boston, Mass. The proposed reservoir has an area of 900 acres, about 60 per cent wooded area, 17 per cent in pasture and meadow, and 23 per cent tillable land. The area involved is sparsely populated, fewer than 40 persons being affected. No railroad lines are involved and only 1.7 miles of highway and a small amount of utility relocation will be required.

36. Preliminary Design Criteria.- The reservoir is designed to control a flood of about the magnitude of that of March 1936, having a flood control storage capacity of 16,000 acre-feet with spillway at elevation 946. This capacity is equivalent to 6.8 inches of run-off over the 44 square miles of drainage area controlled. It is planned to provide gate-controlled outlet capacity sufficient to empty the reservoir in 10 days from full pool. The design discharge for flood control operation is 650 cubic feet per second. The spillway weir will be of concrete, 87 feet long, located in a cut 2800 feet long through a saddle 3.5 miles north of the dam site. The spillway will discharge

18,000 cubic feet per second with a surcharge of 16 feet, leaving a freeboard of 5 feet from the top of the earth dam. The dam will contain 244,000 cubic yards of rock and earth fill, having a top width of 25 feet at elevation 967 and side slopes of about 1 on 3. Details of the design criteria and a lay-out of the structures proposed are given in an appendix - Section A.

37. Estimate of Cost.- The estimated first cost of the proposed West Peterboro Reservoir is as follows:

Construction (for flood control)	$ 1,000,000
Penstock intake and related facilities . .	84,000
Lands, rights-of-way, and relocations . .	216,000
Total Estimated First Cost	$ 1,300,000

The annual carrying charges for the project, including provisions for future power development, computed with interest at 3-1/2% on the entire cost as a Federal investment and amortization of fixed parts in 50 years and movable parts in 25 years, are $60,230. Details of the estimate of cost and computation of carrying charges are given in the appendix, Section A.

38. Benefits of West Peterboro Reservoir.- The proposed reservoir will eliminate about 60 per cent of the flood damage possible from major floods such as in 1936 and 1938 on the Contoocook River from Peterboro to West Henniker and will afford additional reduction in flood damages on the Merrimack River. The total annual benefits, computed as described in the appendix, Section B, will be $58,000. The ratio of benefits to costs is 0.96.

39. Provisions for Possible Future Power Development.- The plan outlined above for West Peterboro Reservoir is for flood control only. The site is favorable, however, for additional storage for conservation and for development of hydroelectric power in the future. These possibilities are discussed in Section IV of this report. The plan

embodies the necessary provisions, such as penstock intake and embankment section capable of being built higher, to allow for possible further development of the site as a miltiple-purpose project. The estimated cost of making these provisions is $84,000.

40. Local Flood Protection Possibilities.- As illustrated on Plate 3, the flood control measures contemplated under the existing project will reduce the damages possible from floods of the magnitude of that of March 1936 to minor proportions along the main stream except at Manchester, Lowell, Lawrence and Haverhill. At Franklin, Penacook, Concord and Nashua in New Hampshire, reservoir control will afford practically complete protection. Even in the larger cities downstream the remaining damages possible will be of such infrequent occurrence that the average annual value of the losses is too small to justify extensive local flood protection measures. The flood problems and possibilities for local protection at these cities are discussed in the following paragraphs.

41. Manchester, N.H.- Above Amoskeag Dam at Manchester, the remaining flood damages to be expected are small, of infrequent probable occurrence, and in scattered areas not susceptible to protection by local measures. Flood protection in this reach will be virtually complete. Below Amoskeag Dam, the effect of the reservoir system will preclude any appreciable damage except to the mill buildings which occupy most of the river front through the city. In general, however, only the basement areas of these mill buildings would be flooded if 1936 flood conditions should be duplicated in the future for the reservoirs will reduce the flood stage 11.4 feet. About one million square feet of mill building floor space were flooded above the first floor level in 1936, the depth of flooding ranging from 1 to 18 feet. If the same flood should recur with the reservoir system in operation, 80 per cent of this space would be safe from flooding, most of it with

a freeboard of 4 feet or more. Practically complete flood protection, therefore, is afforded for the space above first floor levels. In general, the cost of protection or alteration of the basement areas would greatly exceed the prospective benefits. The most economical means of eliminating the remaining possible flood damage would be to abandon the basement areas or to provide minor alterations to the mills so that flooding them would not endanger or put out of service the remainder of the property or preclude use of the basement areas for temporary storage or mobile operations.

42. Lowell, Mass.- The reservoir system, together with local channel improvements already completed and dikes and walls contemplated, will prevent practically all major flood damage in the Lowell area except in the manufacturing district below Pawtucket Dam. Above Pawtucket Dam, the reservoirs will reduce major floods about 6 feet, and only isolated developments at very low elevations near the river would be affected. In the residential areas below Pawtucket Dam, channel improvements and reservoir control will afford a reduction in stage of about 8 feet for a flood of the magnitude of that of 1936. Local protective measures contemplated will provide complete protection for the major residential areas. In the manufacturing district, one million square feet of main floor space were flooded in March 1936 to depths ranging from 1 to 13 feet. Upon completion of existing project measures, about one-third of this space would be safe from flooding if the 1936 flood should recur, another third would be subject to flooding only one or two feet, or below window levels, and the remaining third would be flooded a maximum of 6 feet. Actually, the degree of protection afforded this area is greater than appears by reference to a flood of such rare frequency as that of 1936. For a flood of the magnitude to be expected about once in a hundred years, practically all main floor space will be safe from flooding.

43. Lawrence, Mass.- Reservoir control, together with measures contemplated by local authorities, will prevent practically all possible flood damage above Essex Dam in Lawrence. From the dam downstream to the mouth of the Shawsheen River, both banks of the Merrimack River are occupied by large mills and manufacturing establishments. About two million square feet of main floor space were flooded in this section in 1936, the depth ranging from 1 to 11 feet. About half of this space would be protected from flooding if a similar flood should occur again with the reservoirs in operation and the entire area would be protected for a flood of 100-year frequency. Below the mill area in Lawrence, flood protection will be virtually complete. The residential areas along the Shawsheen River in South Lawrence and North Andover will be afforded complete protection by the reservoir control together with local measures contemplated.

44. Haverhill, Mass.- Reservoir control, together with the flood wall constructed with Emergency Relief funds, will give complete protection for the main business district of Haverhill. The damages possible from major floods in the remainder of the city are small. In general, the developments still subject to flooding are too scattered for economical local flood protective measures. The remaining flood problem in this section can best be taken care of by gradual readjustment of the few remaining properties affected.

45. Discussion.- Existing project measures will prevent about 69 per cent of the average annual flood losses possible on the main stream and principal tributaries. The proposed West Peterboro Reservoir will bring the degree of protection for the Contoocook Valley to nearly 70 per cent and will raise the percentage for the basin area to 72 per cent. Additional control on the Pemigewasset would increase the total to 77 per cent. These percentages represent the degree of protection afforded against all floods up to the estimated maximum

probable flood which is 15 per cent greater than the maximum flood of record in 1936 and, therefore, constitute an extreme criterion for effectiveness of the flood control measures. The amount of control afforded is sufficient to prevent practically all damage from ordinary floods and to reduce losses from extreme floods, such as in 1936, to a small fraction of the amount that would be experienced without control.

46. Conclusions.- Additional flood control on the Pemigewasset River can be obtained most economically through a multiple-purpose development at Livermore Falls, in conjunction with Franklin Falls Reservoir. The economic development of this project depends, however, on the realization of a substantial amount of revenue from power production and its construction should not be undertaken until warranted by a demand for power (see Section IV). Construction of the proposed West Peterboro Reservoir for flood control is justified at this time. The ratio of tangible flood control benefits to costs is practically unity and the intangible benefits of the high degree of flood protection afforded for an important section of the Contoocook Valley are more than sufficient to justify the project. Local flood protective measures, other than those contemplated as related flood control works under the authorized project, are not warranted at this time.

IV. WATER POWER

47. Existing Development.- The Merrimack Basin has been extensively developed for water power, about 5100 feet of head having been utilized in over 130 installations totalling some 200,000 horsepower. About 62 per cent of the total capacity is on the main stream, comprising the Merrimack and the Pemigewasset Rivers. Pertinent data on the principal plants, compiled from information furnished by the United States Geological Survey, the New England Regional Planning Commission, and the New Hampshire Water Resources Board, are shown in Table 8. Much of the developed head on the tributaries is at individual, isolated plants employing direct drive for manufacturing processes. (Principal river profiles are shown on Plate 5.)

TABLE 8 - WATER POWER INSTALLATIONS - MERRIMACK RIVER BASIN

Stream and Location or Name of Plant	Ownership	Principal Use	Operating Head (ft.)	Installed Capacity (H.P.)	Cumulative Storage (acre-ft.)
MERRIMACK RIVER					
Sewalls Falls, N.H.	Concord Elec. Co.	U	16	3,000	300,800
Garvins Falls, N.H.	Pub.Serv.Co. of N.H.	U	28	11,230	300,800
Hooksett, N.H.	do	U	14	2,150	314,600
Manchester, N.H.	do	U	46	33,910	325,500
Lowell, Mass.	Prop.of Locks & Canals (various lessees)	M	36	32,200	334,800
Lawrence, Mass.	Essex Co.(various lessees)	M	28	21,970	339,400
Total for the Merrimack River			168	104,460	339,400
PEMIGEWASSET WATERSHED					
Main Stream					
Ayers Island	Pub.Serv.Co. of N.H.	U	80	13,200	46,000
Eastman Falls	do	U	33	2,700	73,500
Pemigewasset Tributaries	Various Owners	M	402	5,135	73,500
Total for the Pemigewasset Watershed			515	22,705	73,500
OTHER TRIBUTARIES					
Winnipesaukee Watershed	Various Owners	M-U	262*	6,980	210,000
Contoocook Watershed	do	M	673*	15,054	17,300
Suncook Watershed	do	M	112*	4,420	13,800
Piscataquog Watershed	do	U	108	9,185	10,900
Souhegan Watershed	do	M-U	197	2,755	300
Nashua Watershed	do	M	800*	19,585	9,000
Concord Watershed	do	M	282*	3,600	4,600
All others	do	M	-	5,445	19,000
Total for all tributaries (including Pemigewasset)				89,709	358,400
Total for the Merrimack Basin				194,169	358,400

M - Manufacturing
U - Utility

*Estimated from information available.

48. Provisions for Future Power Development at Existing Project Reservoirs.- Provisions have been made for installation of penstock intakes and related facilities for the possible development of power in the future at each of the flood control reservoirs selected for construction under the existing flood control project, namely: Franklin Falls, Blackwater, and Hopkinton-Everett. The ultimate possibilities of these sites are as outlined in the tabulation following: (Also, see Plate 5.)

TABLE 9 - PROVISIONS FOR FUTURE POWER AT EXISTING PROJECT RESERVOIRS

Item	Franklin Falls	Blackwater	Hopkinton-Everett	Total
Estimated cost of provisions at this time for future power development	$ 395,000	$ 180,000	$ 125,000	$ 700,000
Nature of provisions	23' diam. power tunnel	16' diam. penstock intake & wide base dam	2 - 10'x15' power intakes	
Amount of power storage possible in future (acre-feet)	94,000	69,000	16,000	179,000
Probable future power installation in kilowatts	9,200	14,000	5,000	28,200
Gross power head - feet	60	213	41	
Estimated average annual output in kwhrs.	46,000,000*	22,000,000	13,000,000	81,000,000
Estimated additional cost necessary in future	$1,783,000*	$3,383,000	$ 831,000	$5,997,000

* See paragraph 49, following.

49. Possible Development of Franklin Falls and Livermore Falls Sites.- The generation of power at the Franklin Falls site in the future is contingent upon the development of the Livermore Falls site upstream as a multiple-purpose project for flood control and power. If this project were undertaken, it would be possible to use a portion of the storage at Franklin Falls (now reserved entirely for flood control) for power purposes. The

combined development would afford a small increase in annual flood control benefits over the amount obtainable with the present reservoir at Franklin Falls for flood control alone. A summary of a possible plan for a future combined development of these sites is as follows:

TABLE 10 - DATA ON POSSIBLE COMBINED DEVELOPMENT AT FRANKLIN FALLS AND LIVERMORE FALLS

Item	Franklin Falls Reservoir	Livermore Falls Reservoir	Total Combined Development
Total storage capacity (acre-feet)	170,000	350,000	520,000
% of storage for flood control	44.7	37.1	39.6
% of storage for power	55.3	62.9	60.4
Probable power installation in kilowatts	9,200*	21,000	30,200
Firm capacity in kilowatts	7,000*	17,000	24,000
Mean effective head for power	47.5	122	-
Annual energy output in kw-hrs.	46,000,000	56,000,000	102,000,000
Estimated Costs			
For flood control	$3,569,000	$4,576,000	$ 8,145,000
For power	6,419,000	9,624,000	16,043,000
Total ultimate cost	$9,988,000	$14,200,000	$24,188,000
Annual Carrying Charges			
For flood control	$ 170,670	$ 211,230	$ 381,900
For power	325,900	483,020	808,920
Total annual charges	$ 496,570	$ 694,250	$ 1,190,820
Annual Power Benefits			
At site:			
Firm capacity at $11.50/kw.	$ 80,500	$ 195,500	$ 276,000
Energy at 3.3 mills/kw-hr.	151,800	184,800	336,600
At downstream plants:			
20,600 kw. at $11.50	-	-	236,900
32,000,000 kw-hrs. at 3.3 mills	-	-	105,600
Total annual power benefits			$ 955,100
Ratio - power benefits to power charges	-	-	1.18
Additional annual flood control benefits over present Franklin Falls	-	-	$ 83,000
Additional annual flood control costs over present Franklin Falls			$ 14,000

* Recommended by Federal Power Commission

50. Other Potential Power Development.- The more favorable water power sites in the watershed have been developed. In addition to the possible ultimate developments described above, and aside from possible redevelopment of existing installations, there remain several potential sites, principally on the tributaries, involving considerable head, but these require the development of additional power storage for their economic utilization. An investigation of possible development of a number of these sites in the Contoocook River Basin as multiple-purpose projects has been made, but none has been found to afford sufficient flood control value to warrant consideration for development at this time. Studies of the proposed West Peterboro Reservoir for this report indicate that this site may have value for power in the future. If the site were developed for combined flood control and power storage to elevation 968, 32,800 acre-feet of storage would be available for power purposes. Using 6,000 acre-feet for dead storage, the remaining 26,800 acre-feet will afford a dependable flow of 56 c.f.s., equivalent to 1.26 c.f.s. per square mile of the tributary area. Accordingly, it is proposed to have the initial flood control structure adapted for possible future raising and contain a 9-foot penstock intake to provide for an ultimate installation of a 5,000-kilowatt plant for operation at a primary load factor of 11.3%. Pertinent data on a possible ultimate development at West Peterboro are summarized in the following tabulation. The cost figures shown include the initial cost of $1,300,000 estimated for the flood control plan. Detailed estimates of initial and deferred costs and a lay-out of the structures are given in an appendix, Section A.

TABLE 11 - POSSIBLE ULTIMATE DEVELOPMENT - WEST PETERBORO

Item	Flood Control	Power	Total
Storage capacity - in acre-feet	16,000	32,800	48,800
- in % of total	32.8	67.2	100
Range of pool elevations for each use (feet above M.S.L.)	968 to 959	959 to 930	-
Tailwater elevation	-	793	-
Maximum gross power head (feet)	-	166	-
Estimated Costs			
Dam and reservoir	$ 670,650	$1,374,050	$2,044,700
Clearing	10,800	157,500	168,300
Hydroelectric installation (5000 kw)	-	592,380	592,380
Total Estimated Cost	$ 681,450	$2,123,930	$2,805,380
Annual Carrying Charges	$ 31,400	$ 107,200	$ 138,600
Annual Benefits			
Flood control	$ 58,000		$ 58,000
Power at site: 5000 kw at $11.50		$ 57,500	57,500
6,380,000 kw-hrs. at 3.3 mills		21,050	21,050
*Downstream power: 1370 kw at $11.50		15,750	15,750
4,395,000 kw-hrs. at 3.3 mills		14,500	14,500
Total Benefits	$ 58,000	$ 108,800	$ 166,800
Ratio of Benefits to Carrying Charges	1.85	1.02	1.20

*Estimated for the existing plants, as limited by their installed capacities. Peaking benefits computed for 80 per cent load factor operation.

The foregoing analysis is based on the construction of the project in two stages as follows:

First stage - For flood control storage only, with provisions for future power development . . . . $ 1,300,000

Second stage - For flood control and conservation storage (exclusive of hydroelectric installation). . 913,000

Total estimated cost of storage in two stages . . . . . $ 2,213,000

The estimated cost of storage if the project were built to the ultimate height in one stage is . . . . . $ 1,700,000

Details of the conditions which cause the substantial difference in the costs of one-stage and two-stage development are given in the appendix, Section A.

51. General Power Market Conditions.- About 70 per cent of the power consumption in the basin represents the industrial demand, and over 20 per cent is sold to residential customers. The following tabulation, compiled from the Statistical Report of the New Hampshire Public Service Commission for 1937, contains data concerning sales of electric energy by all the public utilities in New Hampshire. Increase in industrial consumption of electric power is dependent principally upon increased industrial activity and upon modernization of existing manufacturing facilities, many of which still employ direct drive. Although it appears that manufacturing in this area is fairly well stabilized, the basin is expected to share in any general increase of industrial activity and some increase in power consumption is being currently observed. Over 80 per cent of the total energy production in the state is hydro-generated, but shortage of hydro power is experienced in low water seasons, necessitating generation by steam.

TABLE 12 - SALES OF ELECTRIC ENERGY, N.H. - 1937

Item	Type of Use	Amount of Energy Sold			No. of Customers Served	Average Consumption per Customer (kw-hr.)	Average Revenue (cents per kw-hr.)
		Total in Millions of kw-hrs.	% of Grand Total (Item No.9)	% of Sub-Total (Item No.7)			
1	Domestic	72.7	6.7	21.6	115,197	634	5.6
2	Commercial (small light & power)	44.7	4.1	13.2	19,523	2,314	5.0
3	Commercial (large light & power)	200.5	18.4	59.4	1,144	175,260	1.3
4	Street lighting	9.4	0.9	2.8	233	40,500	-
5	Elec. railways	4.7	0.4	1.4	4	1,182,300	-
6	Other municipal sales & un-metered sales	5.5	0.5	1.6	1,639	3,360	-
7	Sub-Total, Items 1 - 6	337.5	31.0	100.0	137,740	-	-
8	Sales to Other Public Utilities*	750.0	69.0	-	59	12,711,700	-
9	Grand Total	1,087.5	100.0	-	137,799	-	-

*Principally for export to neighboring states.

52. Discussion.- The possible benefits of the multiple-purpose projects considered above include prospective benefits to existing downstream developments. The full realization of these benefits is not assured at this time. Many existing plants, especially those on the Contoocook River below West Peterboro, are small, individual manufacturing establishments. The ability of these plants to utilize the prospective increase in power capacity and energy sufficiently to justify the cost of the storage is problematical. The Livermore Falls project requires the realization of about a million dollars annually in power revenue. The extent of flood control interest in the project is too small to warrant its development until the power revenue can be definitely assured. Construction of the Livermore Falls Reservoir would involve the discontinuance or migration of one industrial plant of appreciable size, would require the relocation of several miles of railroads and highways, and would, in the opinion of local interests, adversely affect the recreational assets of the Pemigewasset Valley in the vicinity of the reservoir. It is believed that the development of this site should not be undertaken until such time as the demand for additional power exceeds the amounts available at other potential sites in the vicinity which do not have the practical disadvantages involved in the Livermore Falls project. Development of the proposed West Peterboro Reservoir as a multiple-purpose project would require the acquisition of a valuable physical education camp. This property would not be affected by the proposed reservoir for flood control purposes only. Although the estimated cost of developing the ultimate project in two stages is $513,000 greater than for construction in one stage, the flood control benefits definitely obtainable are sufficient to justify the cost of the first stage ($1,300,000), whereas the downstream power benefits necessary to warrant the additional investment of $400,000 initially are problematical. In addition, as a practical consideration, the acquisition of the greater reservoir area at this time would meet with opposition

by local interests. In the future, the relative value to local interests of the prospective power benefits and the commercial and recreational value of the reservoir area may change. It is believed, therefore, that multiple-purpose development of this site should be deferred until such time as the power and power storage on this tributary and the resulting economic benefits are in sufficient demand by prospective beneficiaries to offset the necessary disruption of the development in the reservoir area.

53. Conclusions.- The provisions made for possible development of power in the future at the reservoirs selected for construction under the existing flood control project will make it possible to provide a substantial increase in the available hydroelectric power capacity in this region. The authorization limit for the existing flood control project was based on estimates of cost which did not include allowance for the cost of the provisions for future power development. The existing project should be modified, therefore, to provide for the estimated additional cost of $700,000 required for penstocks and related facilities as authorized in Sec. 4 of the Flood Control Act approved June 28, 1938. The possibilities for development of the proposed West Peterboro Reservoir as a multiple-purpose project are sufficiently favorable to justify the installation of a penstock intake and related facilities in the initial construction at an estimated cost of $84,000.

V. SUMMARY

54. Navigation.- There is no need or justification at this time for modification of the existing project for navigation on the Merrimack River.

55. Flood Control.- Existing project measures will provide a high degree of flood protection throughout the basin. Construction of a flood control reservoir on the Contoocook River near West Peterboro, N.H. is justified. The general benefit of this project is sufficient to warrant the assumption of its entire cost by the Federal Government. Additional flood control measures are not warranted at this time.

56. Flood Warnings.- The effectiveness of flood warning services in preventing flood losses was demonstrated during the September 1938 flood in this basin. Continuation and improvement of existing facilities for flood warnings will tend to minimize the remaining possibilities of flood damage.

57. Zoning Regulations.- Improvement of channel conditions, with resulting flood control benefits, could be obtained by regulations designed to eliminate existing channel encroachments, inadequate channel clearances and further development in areas subject to flooding. Such regulations could be obtained by municipal and state zoning laws. It is the intention of the District Engineer to make available to all local interests the data on the flood situation in their localities with a view to long-range planning for any remaining flood problems.

58. Water Power.- The existing flood control project should be modified to provide for the increase of $700,000 in the estimated cost of the existing project reservoirs due to the inclusion of penstock intakes and related facilities as authorized by Section 4 of the Flood Control Act approved June 28, 1938. The future power possibilities of the

proposed West Peterboro Reservoir warrant the inclusion of a penstock intake and related facilities at an estimated cost of $84,000.

59. Water Supply.- Only a few communities in the basin, notably the city of Lawrence, Mass., obtain water from those portions of the river where improvement of flow and reduction of pollution would be of benefit. This factor should be considered, however, in connection with the possible future development of conservation storage as provided for in existing project flood control reservoirs.

60. Pollution Abatement.- The need for the abatement of pollution on the Merrimack River has been conclusively borne out by the many investigations and reports that have been made over a long period of time, principally by the Massachusetts Department of Public Health. Complete local treatment systems would adequately reduce the hazards of pollution. State authorities estimate that the cost of such works for the thirteen municipalities in the Massachusetts portion of the Merrimack River would be $20,088,000. Partial treatment works for these same municipalities at an estimated cost of $8,400,000, combined with increased low-water flows from conservation storage, would be as effective as the complete treatment system which the Massachusetts Department of Public Health considers necessary. The combination of partial treatment works and increased low-water flows would result in appreciable financial savings compared with the construction of complete local treatment systems. The development of flood control reservoirs as multiple-purpose projects in the future will afford such increases in low-water flow. This factor should be taken into account when the ultimate development of these reservoirs is considered in the future.

61. Recreation and Wild Life Conservation.- Streams, lakes and ponds in the headwater and upland portions of the Merrimack Basin have been highly developed for recreational purposes. Because of the importance of the recreational assets of the region, considerable attention has been given to preserving the scenic values inherent in the streams, lakes and ponds in the study and selection of flood control reservoirs. No definite measures, such as recreation pools or wild life sanctuaries are contemplated in connection with flood control reservoirs at this time, but no measures have been undertaken which will affect these interests adversely.

62. Recommendations.- It is recommended that the existing project for the Merrimack River Basin, authorized by the Flood Control Act approved June 22, 1936, and modified by the Flood Control Act approved June 28, 1938, be modified to provide for the increase of $700,000 over the estimated cost of $21,000,000 previously approved for reservoirs and related flood control works, due to the inclusion of penstock intakes and related facilities as authorized by Section 4 of the Flood Control Act approved June 28, 1938 and for the construction of the West Peterboro Reservoir at an estimated cost of $1,084,000 for construction and $216,000 for lands, rights-of-way and relocations, bringing the total authorized expenditure for the Merrimack River Basin to $23,000,000.

A. K. B. Lyman
Colonel, Corps of Engineers
District Engineer

Inclosures:
Plate 1 - Merrimack River Basin
Plate 2 - Merrimack River
Plate 3 - Graphs of Flood Damage and Flood Stage } attached
Plate 4 - Tributary Components
Plate 5 - River Profiles

Appendix (in separate volume):
Section A - Design and Cost Data } a - 5 copies
Section B - Data for Economic Justification

Merrimack R. 7/21.13

Subject: Survey Report for Navigation, Flood Control and Water Power Merrimack River, Massachusetts and New Hampshire.

1st Ind.

Office, Division Engineer, NORTH ATLANTIC DIVISION, New York City, April 11, 1940 - To the Chief of Engineers, U. S. Army.

1. I concur in the conclusion of the District Engineer that modification of the existing project for navigation is not warranted at this time.

2. I concur in the conclusion of the District Engineer that modification of the existing project for flood control is justified to the extent of constructing a reservoir at West Peterboro, New Hampshire, for its benefits to an important section of the Contoocook Valley and for its additional benefits to the Merrimack River. The estimated cost of this reservoir is $1,300,000. The estimated annual charges are $60,230. The average annual tangible benefits are approximately equal to the annual charges.

3. The existing project for flood control in the Merrimack River Basin provides for reservoirs and related flood control works at an estimated cost of $21,000,000. Reservoirs have been authorized or approved to the limit of this authorization. Certain related flood control works for local protection are justified and are contemplated.

4. Provisions for future power development are being made in the reservoirs of the existing project. The estimated cost of these facilities is $700,000. This was not contemplated in the estimates upon which the existing authorization was based, and has reduced the funds available for flood control by that amount. Modification of the existing project therefore should provide for this additional cost.

5. The District Engineer has studied the possibility of providing protection for upstream areas by headwater flood control reservoirs and by reservoirs for multiple purposes. Except for the West Peterboro Reservoir recommended, he has been unable to find justification at this time for such additional reservoirs. The development of multiple-purpose reservoirs for power and flood control is not recommended until warranted by a demand for power. Local protective measures other than those contemplated under the existing project cannot be justified at this time.

6. Damages from floods on streams in the Merrimack River Basin are aggravated at many places by encroachments on the flood channel. The continuation of unrestricted encroachment upon the high-water channels will ultimately nullify the benefit of works for flood protection. Preservation of the value of the Federal investment in these works requires the promulgation of regulations by State or local authorities restricting encroachments. Such regulations should be subject to review by the Secretary of War.

7. I concur in the recommendations of the District Engineer that the existing flood control project for the Merrimack River Basin be modified to provide for increased flood protection, substantially as recommended by the District Engineer, at an estimated cost, in addition to existing authorizations, of $2,000,000, provided that the states or localities which benefit by the project adopt suitable regulations acceptable to the Secretary of War restricting encroachments upon the flood channels affected by the works.

C. L. HALL
Colonel, Corps of Engineers
Acting Division Engineer

RJH:CEB
ac

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21.13-a in quad.

WAR DEPARTMENT

CORPS OF ENGINEERS, U S ARMY

PLATE 1

MERRIMACK RIVER BASIN
MASSACHUSETTS & NEW HAMPSHIRE

SCALE IN MILES 5 0 5 10 15

U. S. ENGINEER OFFICE, BOSTON, MASS.

APPROVAL RECOMMENDED
Gilbertson
CAPT. CORPS OF ENGINEERS

APPROVED
A T Bluemau
COL., CORPS OF ENGINEERS
DISTRICT ENGINEER

SUBMITTED
John L. Allen
SENIOR ENGINEER

TO ACCOMPANY REPORT
DATED APRIL 1, 1940

PREPARED BY:
Eugene W. Weber
ENGINEER

TR. BY HDH
CK. BY EWW

FILE NO.
M100-40/1

LOCATION MAP

SCALE IN MILES 20 0 20 40 60

LEGEND

- Existing Water Surfaces -- controlled or partially controlled.
- Reservoirs under construction or proposed under existing project
- Reservoirs recommended at this time in addition to existing project
- Drainage area controlled by various water surfaces
- P — Flood control dams which are to contain penstock intakes and related facilities for possible future development of power.
- A — Dikes or walls contemplated under existing authorized project.
- E — Channel improvements completed with ERA funds
- E — Dikes or walls completed with ERA funds.
- W — Dikes or walls completed or planned as WPA projects sponsored by local interests
- 50 — River miles above Newburyport Light

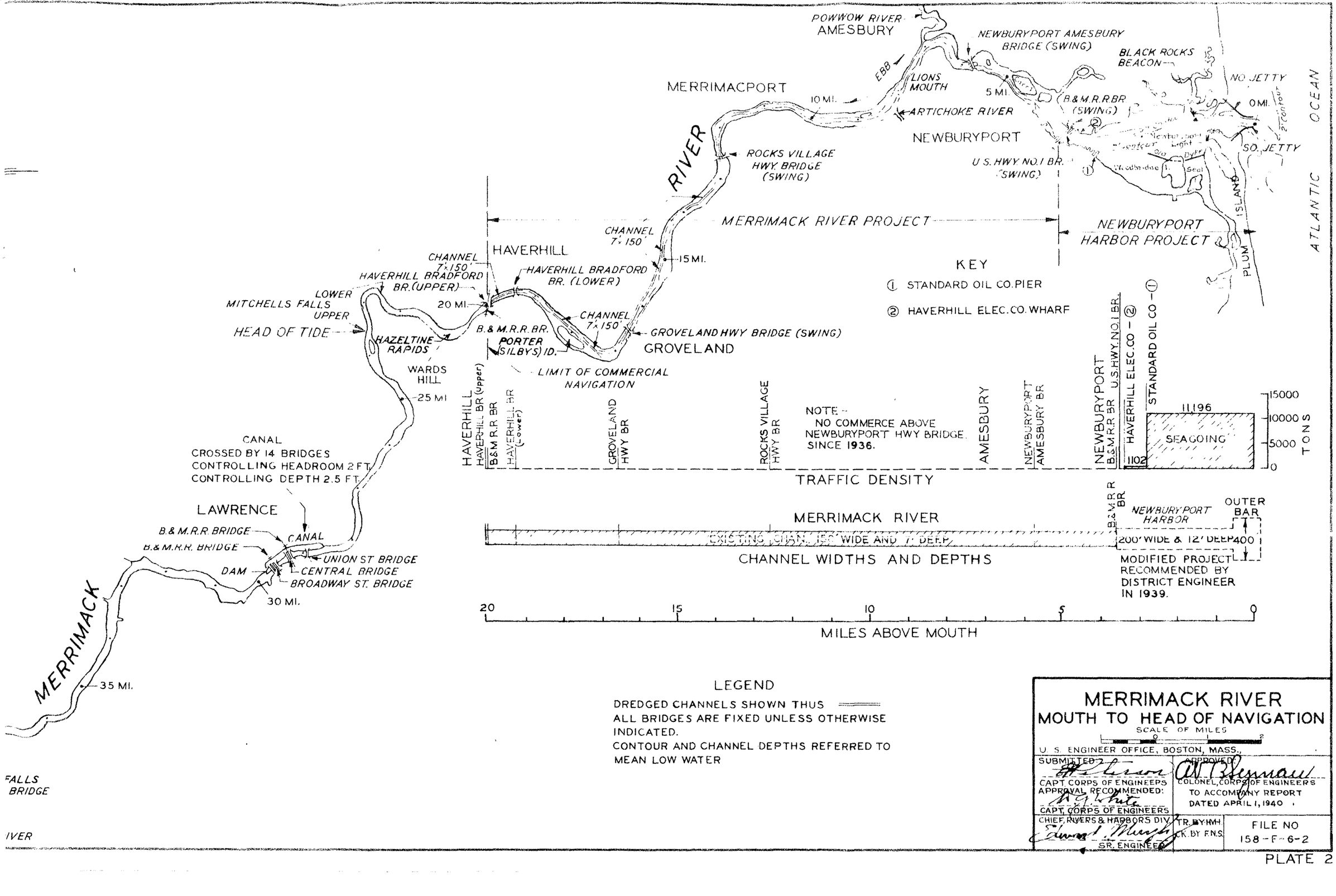
Cities and Towns

Population	over	25,000
"	10,000 to	25,000
"	5,000 to	10,000
"	1,000 to	5,000
"	under	1,000

Section improved for navigation See Plate 2

Note
Flow from these areas diverted for Metropolitan District Water Supply

CORPS OF ENGINEERS U.S. ARMY



LEGEND

DREDGED CHANNELS SHOWN THUS ═══

ALL BRIDGES ARE FIXED UNLESS OTHERWISE INDICATED.

CONTOUR AND CHANNEL DEPTHS REFERRED TO MEAN LOW WATER

MERRIMACK RIVER
MOUTH TO HEAD OF NAVIGATION

SCALE OF MILES 0 1 2

U. S. ENGINEER OFFICE, BOSTON, MASS.,

SUBMITTED:
CAPT. CORPS OF ENGINEERS
APPROVAL RECOMMENDED:
CAPT. CORPS OF ENGINEERS
CHIEF, RIVERS & HARBORS DIV.
SR. ENGINEER

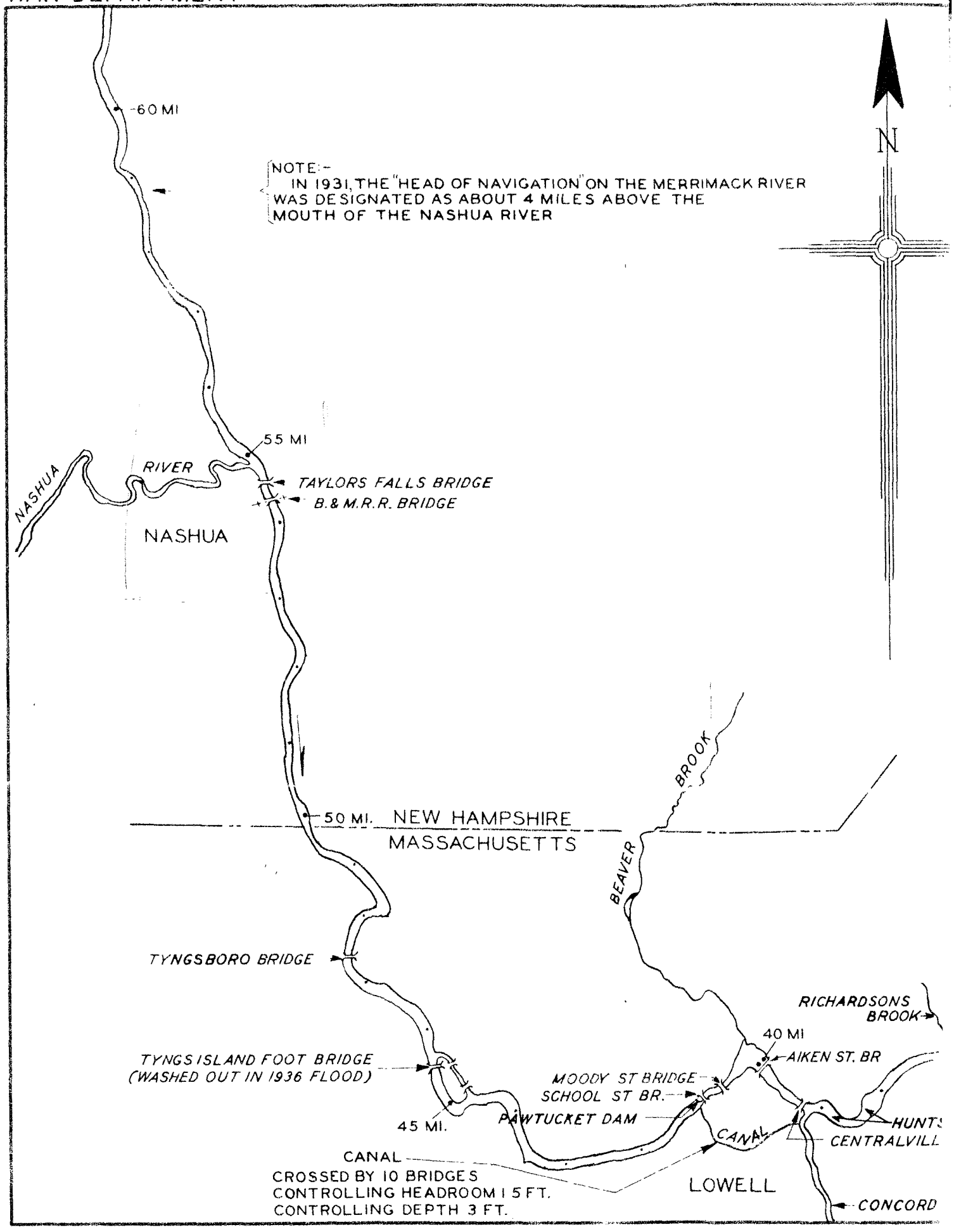
APPROVED:
COLONEL, CORPS OF ENGINEERS
TO ACCOMPANY REPORT
DATED APRIL 1, 1940.

TR. BY MH
CK. BY F.N.S.

FILE NO
158-F-6-2

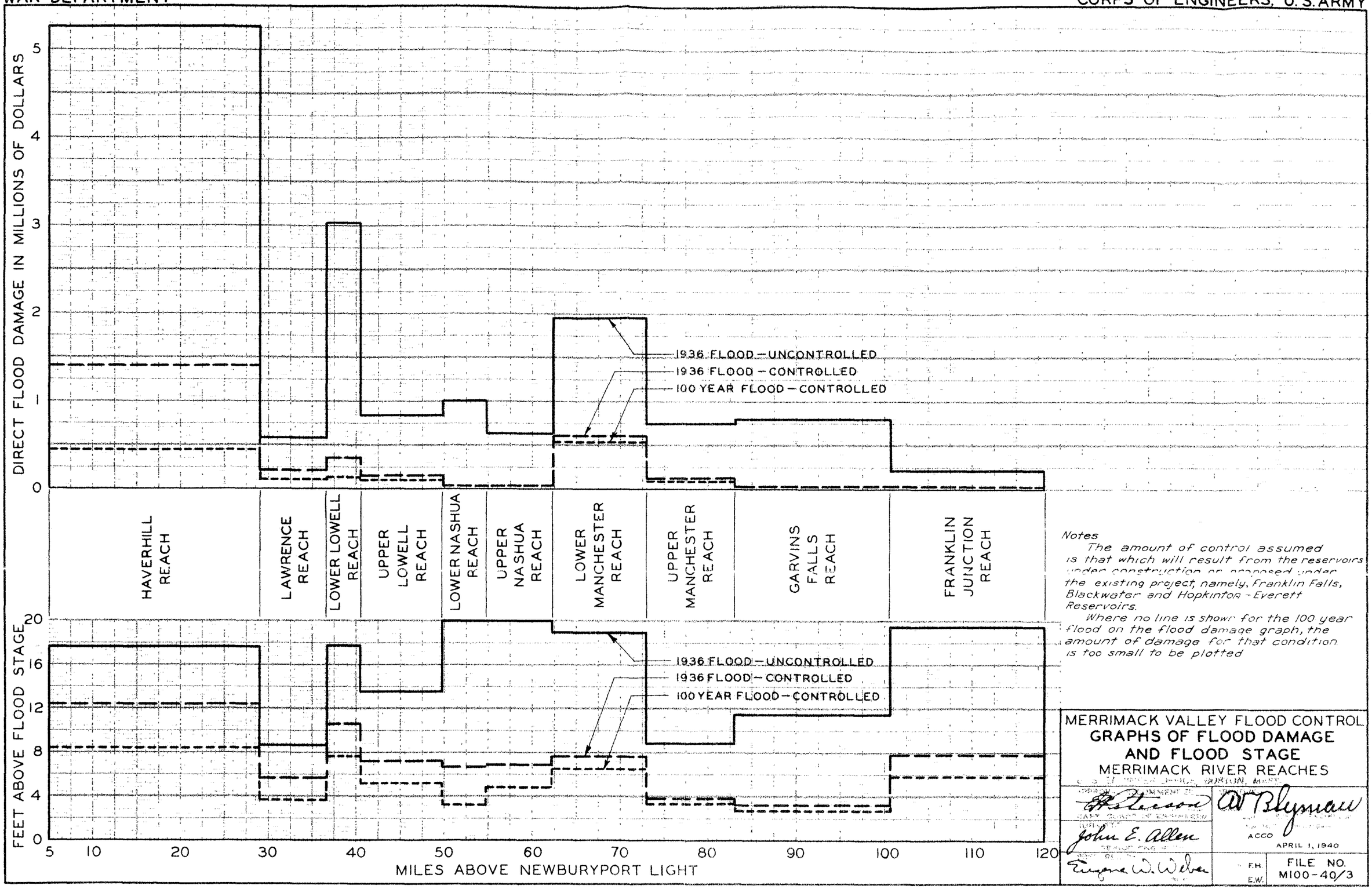
PLATE 2

WAR DEPARTMENT



WAR DEPARTMENT

CORPS OF ENGINEERS, U.S. ARMY



Notes

The amount of control assumed is that which will result from the reservoirs under construction or proposed under the existing project, namely, Franklin Falls, Blackwater and Hopkinton - Everett Reservoirs.

Where no line is shown for the 100 year flood on the flood damage graph, the amount of damage for that condition is too small to be plotted

MERRIMACK VALLEY FLOOD CONTROL

GRAPHS OF FLOOD DAMAGE AND FLOOD STAGE

MERRIMACK RIVER REACHES

H. Peterson — A. R. Blyman

John E. Allen — ACCO

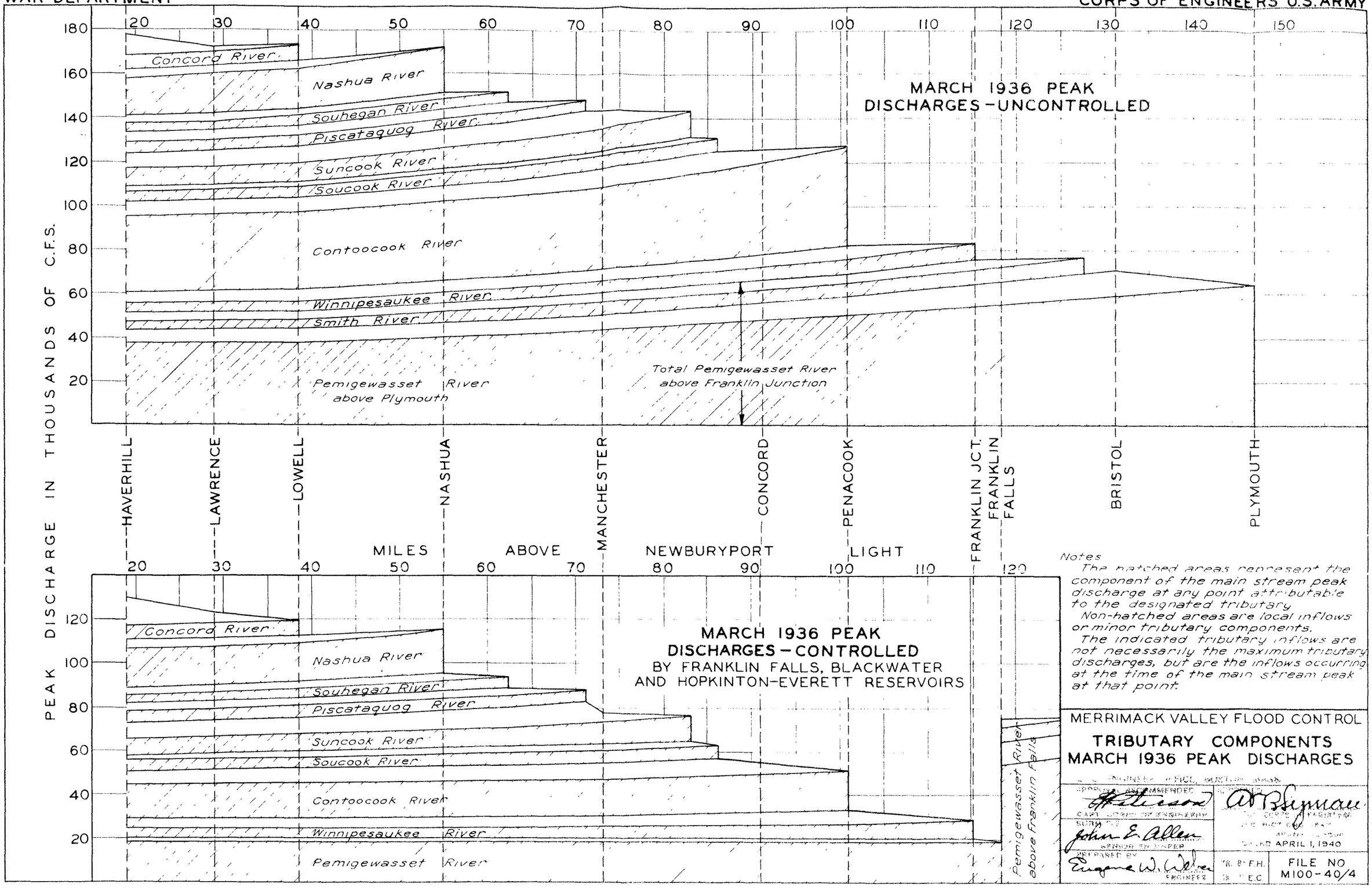
Eugene W. Weber — APRIL 1, 1940

F.H. E.W. — FILE NO. M100-40/3

PLATE 3

WAR DEPARTMENT

CORPS OF ENGINEERS U.S.ARMY



Notes

The hatched areas represent the component of the main stream peak discharge at any point attributable to the designated tributary.

Non-hatched areas are local inflows or minor tributary components.

The indicated tributary inflows are not necessarily the maximum tributary discharges, but are the inflows occurring at the time of the main stream peak at that point.

MERRIMACK VALLEY FLOOD CONTROL

TRIBUTARY COMPONENTS MARCH 1936 PEAK DISCHARGES

SUBMITTED: John E. Allen, SENIOR ENGINEER	APPROVED: A. R. Young, COLONEL, CORPS OF ENGINEERS, DIVISION ENGINEER	
PREPARED BY: Eugene W. Weber, ENGINEER	U.S. ENGINEER OFFICE, BOSTON, MASS. DATED APRIL 1, 1940	FILE NO. M100-40/4

PLATE 4

WAR DEPARTMENT

CORPS OF ENGINEERS U.S ARMY

ELEVATION IN FEET ABOVE MEAN SEA LEVEL

900
800
700
600
500
400
300
200
100

PROPOSED W. PETERBORO RESERVOIR

Contoocook River

Nubanusit Brook

170

P

160

150

140

130

LEGEND

- Flood control dams under existing project.
- Flood control dams recommended in this report.
- Existing dams.
- Flood control dams suitable for future raising.
- (P) Flood control dams which are to contain penstock intakes and related facilities for possible future development of power.
- A.F. Acre feet of flood control storage.
- 50 River miles above Newburyport Light on tributaries.

BLACKWATER

P

46,000 A.F.

120

130

Blackwater River

LIVERMORE FALLS

(See Note)

P

AYERS ISLAND

EVERETT

WEST HOPKINTON

CANAL

P

HOPKINTON-EVERETT RESERVOIR
160,000 A.F.

110

South Branch

No. Branch

80

GREGGS FALLS

Piscataquog River

FRANKLIN FALLS

170,000 A.F.

(See Note)

EASTMAN FALLS

P

Pemigewasset River

Franklin Junction

SEWALLS FALLS

GARVINS FALLS

HOOKSETT

MANCHESTER

MERRIMACK RIVER

LOWELL

LAWRENCE

Note

Ultimate development at Franklin Falls in the future is contingent on development of Livermore Falls as a combined flood control and power project.

20 30 40 50 60 70 80 90 100 110 120 130 140 150

MILES ABOVE NEWBURYPORT LIGHT

MERRIMACK VALLEY FLOOD CONTROL

RIVER PROFILES

MERRIMACK RIVER AND PRINCIPAL TRIBUTARIES

U. S. ENGINEER OFFICE, BOSTON, MASS.

SUBMITTED: John E. Allen, SENIOR ENGINEER

PREPARED BY: Eugene W. Welch, ENGINEER

APPROVED: A. W. Bjerregaard, COL., CORPS OF ENGINEERS, DISTRICT ENGINEER

TO ACCOMPANY REPORT DATED APRIL 1, 1940

TR. BY H.D.H. CK. BY E.G.

FILE NO M100-40/5

PLATE 5